MICHIGAN ENVIRONMENTAL SCIENCE BOARD

FIRE FIGHTER AND CANCER INVESTIGATION PANEL
MEETING SUMMARY
THURSDAY, JANUARY 7, 1999
COURTYARD BY MARRIOTT
7799 CONFERENCE CENTER DRIVE
BRIGHTON, MICHIGAN

PANEL MEMBERS PRESENT
Dr. Lawrence J. Fischer, Chair
Dr. Raymond Y. Demers
Dr. G. Marie Swanson
Dr. Ralph H. Kummler
Mr. Keith G. Harrison, Executive Director

DEQ/OSEP SUPPORT STAFF PRESENT
Mr. Jesse Harrold, Environmental Officer
Ms. Patricia Hiner, Executive Secretary

I. CALL TO ORDER

Dr. Lawrence J. Fischer, Chair, called the meeting of the Michigan Environmental Science Board (MESB) Fire Fighter and Cancer Investigation Panel (Panel) to order at 9:15 a.m.

II. EXECUTIVE DIRECTOR UPDATE

Mr. Harrison provided a brief summary of the material that had been submitted to the Panel to date. He also indicated that future meeting summaries should be available in a more timely manner.

III. PRESENTATIONS

Dr. Alton Greene (Occupational Medicine Fellow, Johns Hopkins University) indicated that he was working with the International Association of Fire Fighters (IAFF) as part of a required two-month rotation. He stated that it was his belief that the majority of scientifically sound studies demonstrate that fire fighters are exposed to many carcinogens and have an increased prevalence of cancer.

There are three phases of fire fighting during which exposure occurs. The first is "knockdown," or active fire fighting, in which respirators and other protective equipment are not 100 percent effective in preventing exposure, especially to substances which enter the body by respiration. Overhaul is the phase which occurs after a fire has been put out. Existing structures are destroyed for safety reasons and to determine the cause of the fire. Respirators are commonly not used at this time, so there is a possibility of inhalation of asbestos and other carcinogens. During the cleanup phase, carcinogens in soot or residue on personal protective equipment may be absorbed,

particularly through hydrated skin.

Fire fighters are also exposed in the firehouses to diesel exhaust, an established carcinogen. Many hours are spent in this environment, where exhaust from fire trucks may lead to high levels of diesel exhaust emission particulates.

Fire fighters are routinely exposed to complex and dynamic mixtures of chemicals that are contained in fire smoke and building debris. The exact nature of these exposures have not been well defined. This is due to the magnitude of new synthetic chemicals produced annually, and the long latency period for many cancers. Adverse health effects are often not identified for many years. However, studies have demonstrated the exposure of fire fighters to various substances which are established carcinogens, one of which is benzene.

Studies in Boston (Treitiman, Burgess and Gold, 1980) found benzene in 181 of 297 samples taken at fire scenes by air sampling units on the chests of fire fighters. Half the samples showed benzene over one part per million (ppm), the current Occupational Safety and Health Administration (OSHA) permissible exposure level, and about five percent were above ten ppm. Benzene was also found at a majority of the fires studied in Dallas (Lowry *et al*., 1985). Similar results were obtained in Buffalo (Brandt-Rauf *et al*., 1988) where benzene was second only to carbon monoxide as the most common chemical substance detected. Even at fires where the smoke intensity was rated as low, benzene was usually present in concentrations ranging from 22 to 54 ppm. Respiratory protection was only partially used or not used at all at these fires. Measurements of respiratory protection efficacy have shown comparable levels of benzene inside and outside of the mask. This is probably due to partial use or nonuse of the mask at the fire, especially after the initial phase of fire knockdown. Respiratory protection is frequently removed during overhaul. Mr. Duffy commented that when the studies were initially done on benzene in 1977, the concern was about its toxicity and not its possibility as a carcinogen. The levels found then, which likely still exist, are of extreme concern today relative to the issue of cancer.

Asbestos is also recognized as a human carcinogen, adding risk to varied occupations. There is both building destruction by fire and demolition by fire fighters, resulting in a high exposure of fire fighters to asbestos fibers. In New York City, Markowitz *et al*., (1992) formed a study of 212 fire fighters who had begun employment at least 24 years previously. Twenty of the 152 fire fighters without prior exposure to asbestos had pleural thickening and/or parenchymal opacities on chest x-rays that represent characteristics sequale of prior asbestos exposure.

The finding of excess risk of lung and pleural fibrosis among fire fighters indicates that significant asbestos exposure has occurred in this group, and there is an excess risk for selected cancers.

Polycyclic aromatic hydrocarbons (PAHs) are a class of organic substances which has been associated with excess risk of a variety of cancers, including cancer of the skin,

lung, kidney, and bladder. Jankovich *et al*. (1991) evaluated the presence of PAHs at the scene of fires. All 14 measured were present at three to 63 $\mu g/m^3$ during knockdown.

Several studies have measured formaldehyde at the scene of fires, with levels of 0.1 to 8.3 ppm found. Levels were higher during knockdown than during overhaul. Airborne concentrations of formaldehyde inside the mask ranged from nondetectable to 0.3 ppm.

There are various cancers prevalent in fire fighters which are associated with carcinogenic occupational exposures. The first is brain cancer, which is often incurable. Suspected causes of brain tumors include vinyl chloride, benzene, PAHs, polychlorinated biphenyls, N-nitroso compounds, trizaenes and hydrazines. Excess risk among fire fighters was most notable within 15 to 30 years of exposure. Tornling, Gustavsson and Hogstedt (1994) was able to find dose-response relationships between brain cancer incidence and increasing age, duration of employment, and years since hire, and between brain cancer mortality and increasing age, duration of employment, and estimated number of fires fought.

Leukemia and lymphoma are associated with environmental and occupational exposure to benzene, which is found in solvents, gasoline and plastics, and 1,3 butadiene, found in tires and synthetic rubber. Fire fighters are exposed to the gases released by these materials as they burn. The majority of epidemiologic studies have found that fire fighters are at an increased risk of leukemia. A recent study combined mortality data from 27 states and reported an excess risk of 2.8 times for firefighters younger than 65. Marked increases in risk were also found for non-Hodgkin's lymphoma. A study (Sama et al., 1990) from the Massachusetts Cancer Registry found a risk of 3.3 times for fire fighters relative to police officers. Howe and Burch (1990) combined the results of cancer mortality studies of fire fighters and concluded that there was evidence of a causal association between multiple myeloma and fire fighting. These are serious as blood cancers are often incurable.

Fire fighters are exposed to chemicals known to cause bladder cancer, and have an increased risk of bladder cancer deaths compared to general population rates. There is also exposure to substances implicated as risk factors for renal cell carcinoma. Fire fighters have also demonstrated an increased risk for prostate cancer. A study in Toronto (Aronson *et al*., 1994) found an overall increased risk of 2.5 times for death from testicular cancer for fire fighters as compared to an average male. The three deaths seen occurred in men with less than 15 years as fire fighters, and within 20 years of first exposure.

Several established occupational exposures increase the risk of cancer of the digestive system. Once cleared from the airways, inhaled particles and related carcinogens can be swallowed and transferred to the gastrointestinal tract, and exert their effect on the digestive epithelium. Of particular relevance to fire fighters are the higher rates of colon and rectal cancer in workers exposed to asbestos. Excess colon and rectal cancer has been found in many studies of fire fighters. Liver cancer, which is usually incurable, is

rare in the United States. A study of fire fighters in San Francisco (Beaumont *et al*., 1991) found a twofold excess of liver cancer mortality relative to the general population.

Although the most common risk factor for skin cancer is prolonged exposure to sunlight, occupational exposure to soot and tars, coke oven emissions, arsenic, and cutting oils has been associated with increased risk. Carcinogenic substances may be absorbed by exposed areas or when protective clothing is permeated. Contact can occur during fire knockdown and overhaul, or during cleaning of clothing or equipment. Feurer and Rosenman (1986) found a 2.7 times increased risk of skin cancer mortality for New Jersey fire fighters relative to the U.S. population, with risk increasing with duration of employment.

In conclusion, fire fighters are exposed to carcinogens in their work environment and the respiratory protection and other personal protective equipment used is of uncertain efficacy in the real world. The protective clothing can even carry carcinogens back to the fire station. Additional uncertainty comes from the wide variety of new chemicals being introduced into housing and commercial structures yearly.

Mr. Richard Duffy (Director, Department of Occupational Health and Safety, International Association of Fire Fighters) stated that he had been involved with occupational safety and health issues for the past 25 years. He said that the IAFF is a labor union, affiliated with the AFL-CIO and the Canadian Labor Congress. It currently represents 225 professional fire fighters employed by various federal, state and local governments, as well as airports, in the United States and Canada. The IAFF is responsible for the development and implementation of all the health and safety aspects of the international union, including the medical residency program.

For about the past 50 years, the IAFF has produced an annual report on the injuries, illnesses and fatalities experienced among the firefighters under their jurisdiction. In the last ten years there have been 352 deaths while on duty, as well as 611 documented occupational disease deaths. Due to the earlier retirement age, this could be a conservative figure for occupational disease deaths. There were also 337,622 injuries. This means that approximately 40 out of every 100 fire fighters are injured beyond normal first aid each year. Also during that ten-year period, there were 7,467 forced retirements due to occupational disease.

There are physiological and psychological stresses experienced by fire fighters. These include a sudden and drastic increase in heart rate produced by the sound of the alarm, as well as the quick transition from the relative calm and safety of the firehouse to the dangers of a raging fire. There are also extremes of temperature, with possible transitions from below freezing temperatures to between 100 and 1,400 degrees Fahrenheit. This can produce frostbite or cardiovascular and pulmonary disorders, such as hypertension, pneumonia, and bronchitis. Fire fighting also involves strenuous activity, made more burdensome by the heavy protective clothing and equipment worn.

Thirty-seven states currently have some type of heart and lung legislation in effect

which recognizes the possibility of occupation-related disease. Worker compensation boards generally have established a history of identifying cancer in fire fighters as an employment related activity. In addition, 16 states and New York City have adopted specific legislation that presumes that if a fire fighter contracts cancer, it's occupationally induced.

Respiratory protection is a difficult issue. The breathing apparatus worn by most fire fighters has the capacity to deliver 40 liters per minute for 30 minutes. Typically, fire fighters can use up to 100 liters per minute in a high work load situation. They are not negligent in purposely not wearing the breathing apparatus in certain situations, but are conserving their air supply for the times of greatest need. It is not feasible to enlarge the tank, as it already weighs 35 pounds. High exposures within the mask occur in two ways. The mask can gather dangerous compounds before being placed on the face. Also, when the fire fighters are breathing at high rates, there is a possibility of negative pressure on the face mask with resultant leakage.

Asbestos will probably remain a concern for a long time. Fire fighters of the present could mirror the exposures and resulting consequences of shipyard workers in the 1940's. The issue of concern is not only the final consequence of mesothelioma, but also the plural plaques and other lung changes.

A study was done with UCLA which measured diesel exposure and PAHs in fire houses. Measurements of diesel soot were taken in the station house as well as on individual fire fighters. This was done in Los Angeles, California and repeated in New York City, New York and Boston, Massachusetts. There were high exposures of up to 750 μg of PAHs which spiked and then reached a plateau. The exposure was kept from going higher by the opening and closing of the fire house doors. So it was felt that departments in smaller cities, with fewer runs, would have equivalent exposures.

Efforts have been made by Dr. Dave Alery of the University of Pittsburgh and others to get furniture and building material manufacturers to measure the toxicity of their individual products. This would allow for the choice of less toxic alternatives by architects and others. Attempts at legislation in this area were successful in a number of states, including New York and California.

One lifestyle issue which is important relative to fire fighters is smoking. The IAFF has stated that fire fighters should not smoke. It has encouraged its affiliated departments to hire nonsmokers, and to help those who do smoke stop this addictive habit. Although percentages of smokers varies by region, being lower in the West, the total number is decreasing. While lung cancer is not the cancer of highest incidence among fire fighters, prevention is still an important issue.

General wellness is also a concern. The IAFF has developed an annual medical program and fitness evaluation for 26,000 fire fighters in ten major fire departments in the U.S. and Canada. Evaluation on an annual basis will allow for preventative measures as well as documentation of possible degradation of health. Tests and

measurements were developed which were specific for fire fighters. This includes specific blood tests as well as prostate analyses for men and mammograms for women. Data will be collected and compiled within the individual departments as well as at the IAFF office in Washington, D.C. Encouraging healthy lifestyles and preventive medicine for fire fighters will help to decrease the need for presumption cancer laws.

Studies which have shown increased adverse health effects in fire fighters are even more remarkable considering the average health status of this work force. Fire fighters are typically hired at a young age and must pass a rigorous medical and physical evaluation. In addition, pension laws which consider the work required and possible injuries or illnesses, allow fire fighters to retire after 20 or 25 years on the job. So there is the possibility of retirement before age 50. So the healthy worker effect must be considered in regards to these studies.

There are those who would say that monetary compensation for cancer in fire fighters is not feasible, that it would add to great a burden to the current system. It is difficult to determine the exact number of additional claims that would be generated. Many fire departments use their individual retirement systems rather than a state worker's compensation program, making it difficult to compile data. The state of California, which has 30,000 paid fire fighters and 33,000 volunteer fire fighters, currently has cancer legislation. The California Public Employee Retirement System is the largest retirement system in the United States and they have stated that the addition of a presumptive cancer benefit for fire fighters has had a minimal effect on the actuarial costs to their system. During the first three years, there were 45 new claims for cancer related disability, with an average claim of $14,000. Illinois adopted presumptive cancer legislation in 1984. They also found no significant actuarial impact. In Oklahoma, claims for cancer accounted for 0.03 percent of the pension costs, at an average cost per claim of $10,000.

In Michigan, there are about 5,500 paid and 24,000 volunteer fire fighters. Based on assumptions from these other states, cancer costs would involve only perhaps 0.034 percent of the Michigan work force. Costs for the program would be about $100,000 to $140,000 per year. In addition, there is a higher mortality rate and shortened life expectancy for the cancers associated with fire fighting compared to other occupational illnesses and injuries. This results in lower average payments when compared to other, longer-lasting conditions.

Dr. Fischer asked how the occupational hazards of fire fighters compared to those of police. Mr. Duffy replied that there are much higher numbers of police, and that they are more likely to deal with violence and the possibility of being shot. However, these two groups are often compared, as being high stress, public employees.

Dr. Kummler asked why Dr. Greene had not included the Aronson study in his presentation. Dr. Greene replied that information was not specifically omitted due to particular problems with that study. Mr. Harrison requested that Dr. Greene provide complete citations for all the studies cited in his presentation, as several had not

previously been seen by the Panel. Dr. Demers questioned whether the work done by Peter Oris had been published. Mr. Duffy said that it was not a published study, but he had gotten the information directly from Mr. Oris who is very involved in this cause.

Mr. Jesse Harrold asked whether other forms of tobacco use were considered when determining that smoking rates were lower in more western regions. Mr. Duffy said that although the rate of chewing tobacco use was increasing, especially among the young, those who were hired as fire fighters were discouraged from any form of tobacco.

Dr. Fischer questioned the validity of considering data which, although demonstrating an increased risk, is not statistically significant. Mr. Duffy responded that he felt the statistical significance was present in relationship to the general public, especially when considering the healthy worker effect. He added that there were many problems in data collection for this group. Fire fighters often have second careers, which are then listed as their occupation on death certificates. Better statistical data are available in places such as Philadelphia, where retirees remain in the union and follow-up data are available.

Dr. Swanson suggested that there could be selection bias in many of the studies which would weaken the evidence presented. Among the many studies considered by the Panel, and even among those presented today, there was no consensus of results. Also, in considering regulatory issues, a dose response relationship is important. Dr. Swanson stated that few of the studies considered were able to show that. Dr. Kummler concurred that this is an important issue. Mr. Duffy answered that some of the inconsistency among studies was due to the differences in geographical locations and different methods of fire fighting. He added that data on dose response were not available and that dose response relationships were difficult to establish due to the problems in dose measurements. Environmental sampling is difficult due to the heat of fires which melt many collection media. Also, different structures are constructed differently and will give varied exposures when they burn. In addition, chemicals are generally measured separately, which does not account for any synergistic effect when they are combined. Using the example of shipbuilders and asbestos, Mr. Duffy stated that people with much smaller doses can get similar cancers to those with high exposures. Number of runs has been used as a measure of dose. However, the variety of exposure between runs, and differences in personnel deployment between different-sized departments makes consistency problematic.

Dr. Demers asked how the level of diesel exhaust and carbon monoxide exposure of fire fighters compared to ambient outdoor air levels. Mr. Duffy stated that exposures were significantly higher than background levels. Dr. Kummler agreed that background levels were normally much lower than those recorded in the studies presented. Dr. Demers also asked whether there was an established value for a national cigarette smoking prevalence. Mr. Duffy responded that although smoking was an important part of a health history, it was difficult to quantify.

Dr. Demers questioned whether there was anything which indicated a rising trend in the

incidence of cancer among fire fighters, and whether there was a change in morbidity due to work conditions which have changed. Mr. Duffy stated that there has been a clear move from fires of wood buildings to many more synthetic products. Although the number of annual fires in this country has decreased, the loss in monetary value and human life has increased. Protective clothing is designed mainly for protection from the heat. Factors which allow for heat dissipation from the body also allow for entrance of toxins. Dr. Fischer asked whether work had been done to define exposures as being either inhalation or dermal. Mr. Duffy responded that assumptions are made based on exposures in other industries. A problem has been the difficulty in wearing respirators and the resultant interest in engineering controls other than respiratory

One factor is the attempt by fire fighters to conserve air, and not always use the tank and respirator. Changing tanks during a fire is done, but is not always practical. It is also more difficult to perform at a high physiological work load for long periods, breathing with the respirator. Attempts to design a mask which can go from an outside source to tank air have not been very successful. The difficulty is compounded by the lack of dexterity caused by protective gloves.

IV. PANEL DISCUSSION

Dr. Fischer stated that the charts presented by the speakers did not demonstrate statistical significance, probably due to the small numbers of persons involved. He questioned if it was important to pay attention to the statistics. Dr. Kummler stated that normally he would. However, while the charts in many review articles typically do not show it, the original studies showed many statistically significant findings. Dr. Swanson stated that in her review of the studies, she had found equivocal results. Not all of the studies were positive, and some of the positive studies were not statistically significant. Also, as an epidemiologist, it is not possible to mix cohort studies with those which are case control. Selection bias is typical of occupational studies. The population selected was not always representative of the general group of fire fighters. Dose response is also an important issue. This could at least be measured by years of service, which was not done. The number of cases is also important and contributes to statistical power. Dr. Swanson stated that statistics should not have been done on these small studies, and they are not high quality epidemiology studies.

Dr. Fischer reminded the Panel that Dr. Sheila Zahm had felt there was some evidence, but she was reluctant to make a final conclusion. Dr. Swanson said that this was reflected in the charts before the Panel. They were suggestive, but not significant. Dr. Kummler then read from the Golden review where it stated that, ". . . a substantial body of literature now exists on the carcinogenic hazards of fire fighting." He added that including the 16 legislative bodies which have approved the presumption, there seems to be a consistent trend of people who regard the literature as linking the occupational hazard. Mr. Harrison countered, that based on his review of the material, it was more often a political process, rather than scientific consensus, that prompted the legislation.

Dr. Demers said that he too was frustrated by the inability to accurately measure the

exposures encountered. Fire fighters do face intense exposures and unlike other professions, are unable to leave the scene when dangerous conditions occur. Dr. Demers also stated that he was somewhat impressed with the number of positive studies. It is bothersome that they are so diverse, with no trend toward one particular site of cancer. However, that is not surprising given the diversity of exposures. Dr. Demers also commented on the possibility of confounders. Information on cigarette smoking is lacking. However, the screening for fire fighters looks for healthy people, and they should not have a higher rate of smoking than the general public. In addition, lung cancer was not one of the main cancer risks for fire fighters. Respiratory protection or the lack of it might be considered a confounder, but in reality this is not a factor which is going to change.

Dr. Demers stated that the healthy worker effect does need more emphasis, with more studies which control for this factor. Dr. Fischer responded that in the Golden review it was stated that the healthy worker effect has less of an impact on cancer than on other causes of death. Dr. Swanson said that increasing knowledge of genetic susceptibility would tend to support that idea. However, this effect is considered an important issue in occupational epidemiology for any disease. A healthy working group will have different risks than the general population, which includes those who are too sick to work, or are disabled. Ways to make comparisons to the general public include exclusion of anyone who is not working. Also, being generally healthy does not mean that one is not susceptible to carcinogens.

Dr. Swanson said that a comparison has been be made to the studies on fire fighters and cardiovascular disease, which showed a very clear connection. There was not a comparable link to cancer. Dr. Demers responded that although studies such as those regarding brain cancer individually deal with small numbers, they could be combined in a meta-analysis the results could be statistically significant.

Dr. Fischer stated that he felt that fire fighters have distinct occupational hazards, including exposure to substances in gaseous form that are cancer causing agents. He questioned whether increased risk from this exposure was enough to say that this is a special problem for this occupation. Dr. Kummler said that, looking at lifetime exposure, he thought that it was. Dr. Swanson said that the problem with lifetime exposure was the possibility of second careers and the difficulty in separating the risks and hazards from the separate occupations.

Mr. Harrold asked whether the aerosolized chemicals produced during a fire had been considered as a hazard unique to fire fighters. Dr. Swanson replied that these would be most likely to produce chronic respiratory conditions or cancer, but lung cancer was not elevated among fire fighters. This weakens the biological plausibility of the risk. Brain cancer, which is common, can be metastatic as well as primary. This is a weakness of the mortality data.

Dr. Fischer asked whether fire fighters were considered to be higher risk takers than the general population in terms of lifestyle. Mr. Duffy said that he didn't think so. He

thought that both drug and alcohol use, as well as smoking, were lower among fire fighters. He also stated that they had healthy habits such as wearing seat belts.

Dr. Demers questioned whether immunogenicity was more likely with a high intensity, low duration exposure than with one which was a chronic, low dose. Dr. Fischer said that he thought that that was likely. Higher intensity exposure would cause more DNA damage which could be translated into a carcinogenic event. Dr. Swanson added the example of sunlight where people who are exposed for brief, intense periods are most at risk for skin cancer. The outcome would depend on whether the chemical was likely to have an initiating or a promoting effect. A promoting effect would be more likely through chronic exposure. Many of the measured exposures, such as benzene, asbestos, and formaldehyde are not at the high levels seen in some other occupations. However, these exposures could still be important, especially considering the conditions of stress and extreme heat experienced by the fire fighters at the time of exposure. Mr. Duffy added that the uniqueness of this occupation is seen in the relationship between the noise levels to which fire fighters are exposed and the incidence of deafness in this group. While they are exposed to sirens and other loud noises, it is not at a level high enough to cause the amount of hearing loss that is seen. Due to possible interaction with carbon monoxide or other factors, there is not a clear dose response relationship.

V. PUBLIC COMMENT

Mr. Paul Hufnagel (Michigan Professional Fire Fighters Union) thanked the Panel for the opportunity to bring speakers to testify. He stated his willingness to provide any additional information he might have. Mr. Duffy reminded the Panel that presumptive cancer legislation does not automatically give benefits to a fire fighter who has cancer. Due to changes initiated by the Internal Revenue Service, states with presumptive cancer laws also have a system of rebuttal. After the diagnosis of cancer is made, it is up to the employer to demonstrate lifestyles or other factors that put the cancer outside of the occupation.

VI. PANEL ASSIGNMENTS

Dr. Swanson stated that it was necessary to construct a formalized set of tables that would show the results of the various studies. The dissimilar methods used precluded doing a meta-analysis. She said that she had a graduate student who would be able to work with her on this. When they had the format defined, Dr. Swanson would send it to the rest of the Panel so that they could add their input. Mr. Duffy added that he had made a chart which compared various studies. He promised to send a copy to the Panel for them to consider. After reviewing the finished tables, the Panel would then attempt to make some conclusions.

In reviewing the charge from the Governor, Dr. Fischer stated that these tables would help to answer the first part, to evaluate the available cancer and occupational health scientific evidence regarding the level of risk to fire fighters from occupational exposure. The second part, determination of the level of risk expected, would be more difficult. It might be possible that the Panel would have to say that either there is a lack of a dose

response relationship, or that there is a lack of data. Mr. Harrison reiterated that what the Governor was interested in was obtaining the best scientific evaluation possible, regardless of what the results of that evaluation might be. Dr. Demers restated that the Philadelphia investigation could provide important data which should be examined if it were available. Dr. Fischer said that the final report from the Panel was expected to be a relatively short document.

VII. NEXT MEETING DATE

An additional meeting was tentatively scheduled for early next month.

VIII. ADJOURNMENT

The meeting was adjourned at 12:32 p.m.

Respectfully submitted,
Keith G. Harrison, M.A., R.S., Cert. Ecol.
Executive Director
Michigan Environmental Science Board